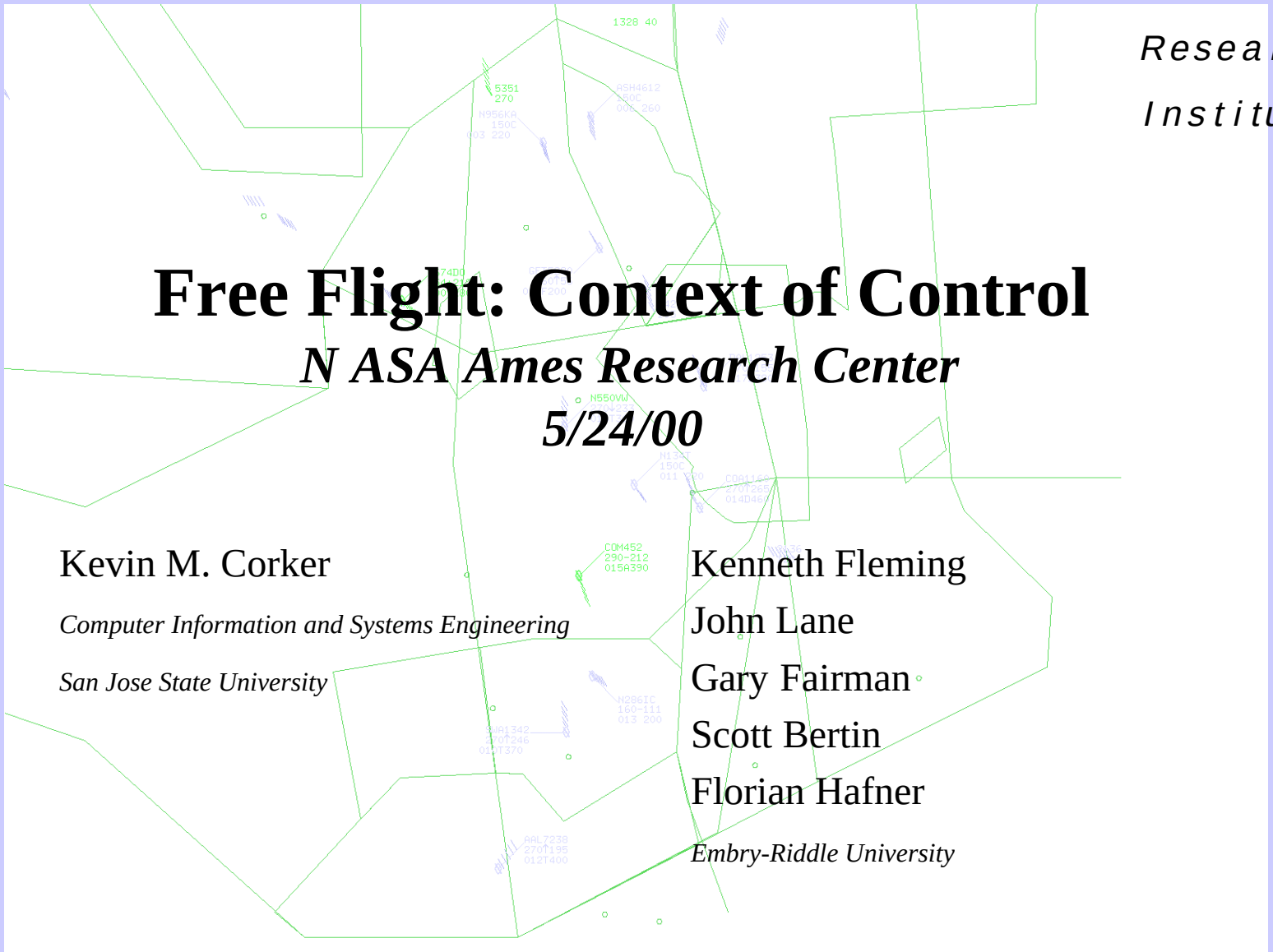
C I S E

San Jose State University

National Aviation Research Institute



Free Flight: Context of Control

N ASA Ames Research Center

5/24/00

Kevin M. Corker

Computer Information and Systems Engineering

San Jose State University

Kenneth Fleming

John Lane

Gary Fairman

Scott Bertin

Florian Hafner

Embry-Riddle University

Experiment Purpose

- Characterize the impact of shifts in separation authority on controllers performance in complex center operation
- Examine the interaction of operational performance measures with the type of control being undertaken by controllers
- Characterize the relationship between subjective workload measures and objective performance measures across the control modes employed.

Presentation Prospectus

- Paradigm
- Self-Separation Impact on Controllers
  - Experiment
  - Results
  - Implications
- Intent and the Context of Control

Paradigm

- Need to consider “vaulting” technologies to bridge gap between current state and final projected state of NAS operations.
  - Technology that is intended for transitional operations
  - Research that identifies the “why” of current operations & the impact on that for future design
- Cannot simply design for end state operations
  - Transition impact on individual practice and organizational performance
- Information is the medium of exchange among NAS participants
  - DAG TM specification for ATSP aiding for: compliance monitoring, negotiation, and user-preference routing
  - However, what information, what intent, how much/how ofen to whom, and how are all under-determined

Experiment Structure

- 8 Controllers* worked in a repeated-measures ordered block design in four conditions of control operation
    - Current
    - Direct-to route request
    - 20 % of traffic self-separating
    - 80% of traffic self-separating
- Traffic density ramped in 20 minute increments across the 60 min. session
    - 0-4, 4-8, 8-12 aircraft
- Controllers were instructed that they were responsible for safe separation and could cancel free flight operations when they felt safety jeopardized or their airspace compromised,

* average experience at facility 9.5 yrs. All had refresher training within the prior 6 months

Experiment Process

- Simulate a complex center operation
  - OCALA Sector traffic and operations*
  - Two Radar Positions and 3 Pseudo-pilot positions
- Design a ramping traffic density consistent with Center densities
- Training 1 hr. on free flight operations, 1 hr. on two practice runs at current and 50 % free flight operations
- Flight strips and collision alert function were available
- Single position operation for R-side
- Workload probe task included as a in-line probe on 5 minute basis across simulation
- Psuedo-pilots were trained ERAU staff

* 87.5% of post simulation questionnaire responses on simulation fidelity were rated good-excellent

Illustration of OCALA sector, traffic & Workload probe task

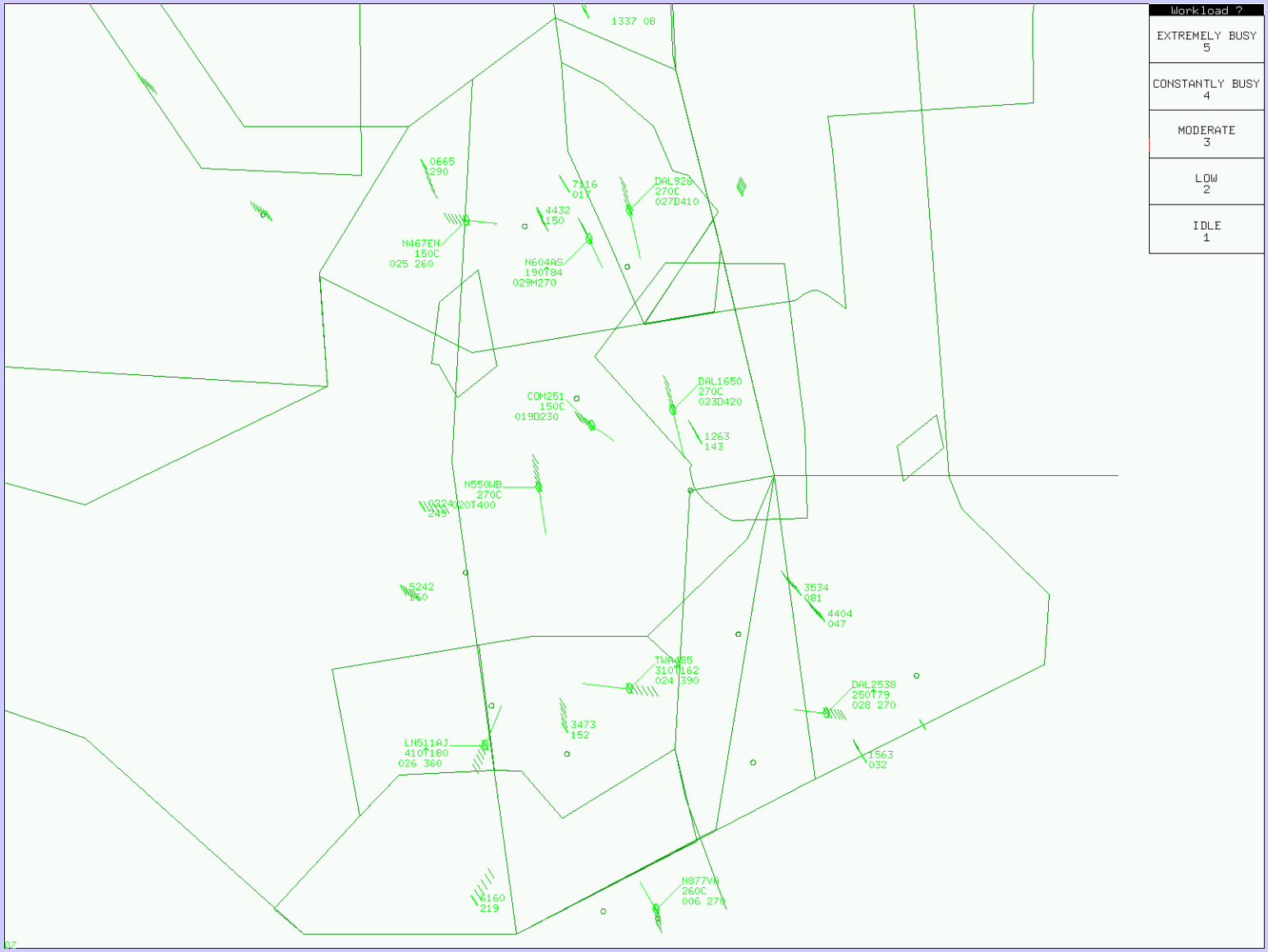
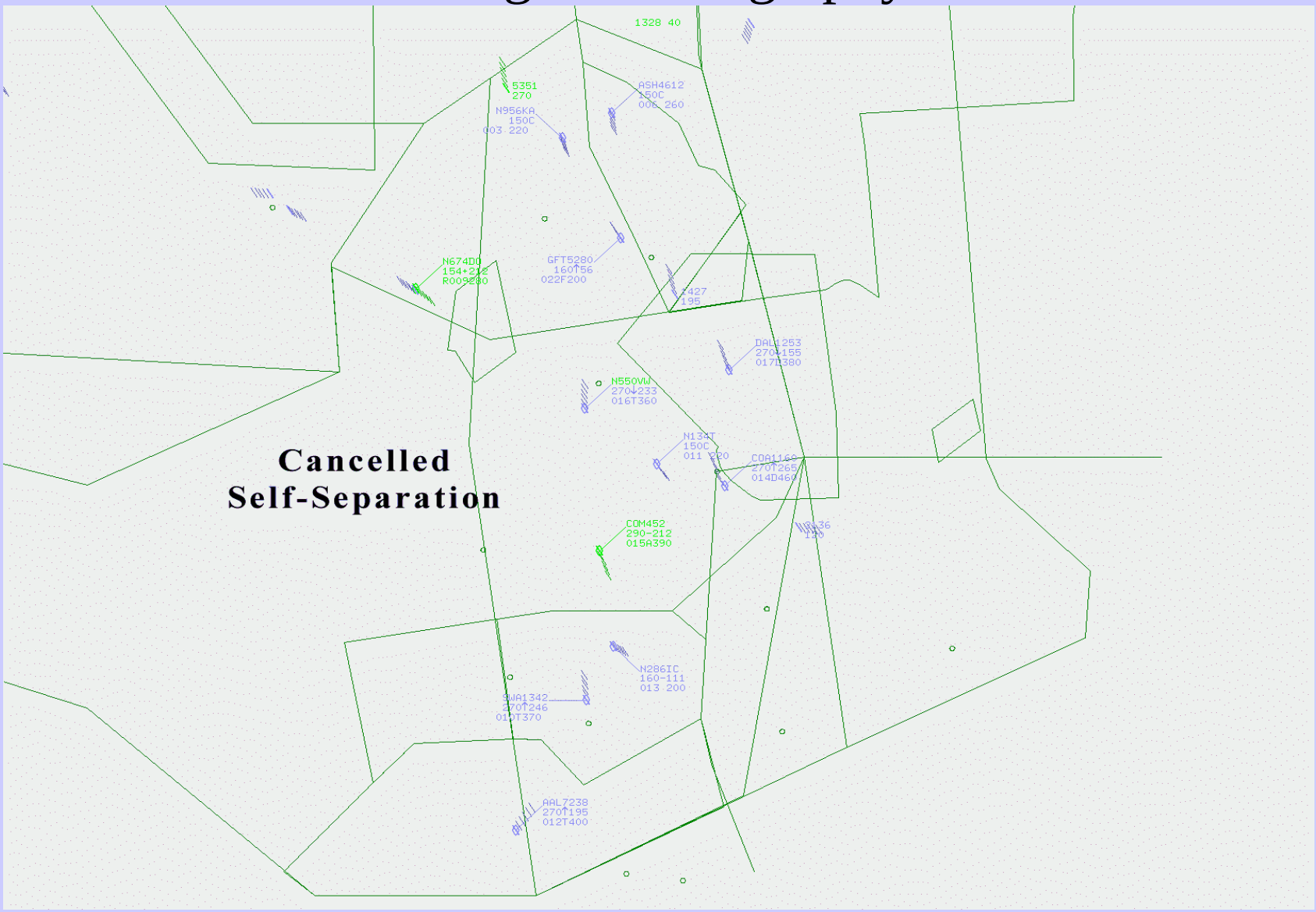


Illustration of OCALA sector, traffic & “cancelled free flight” iconography



Experimental Hypotheses

- Controller Subjective workload will increase with : number of aircraft, and type of control situation (full control, direct routings, vs. self-separation) UPHELD
- Controllers will exercise the cancellation of free flight option in cases of self separating aircraft, and more in the 80 % condition than in the 20% condition. NOT UPHELD
- Control of small numbers of self separating aircraft will lessen subjective workload considerations relative to fully controlled situations and or majority free flight situation. NOT UPHELD
- Controllers will find it more difficult to handle aircraft in a free flight mode as the number of aircraft increase. Predicted interaction of aircraft number and control mode UPHELD
- Controllers will solicit intentions from free flying aircraft if they do not have sufficient tactical information. There will be a significant interaction effect between number of Self-separating aircraft and communications time. UPHELD

Experimental Measures

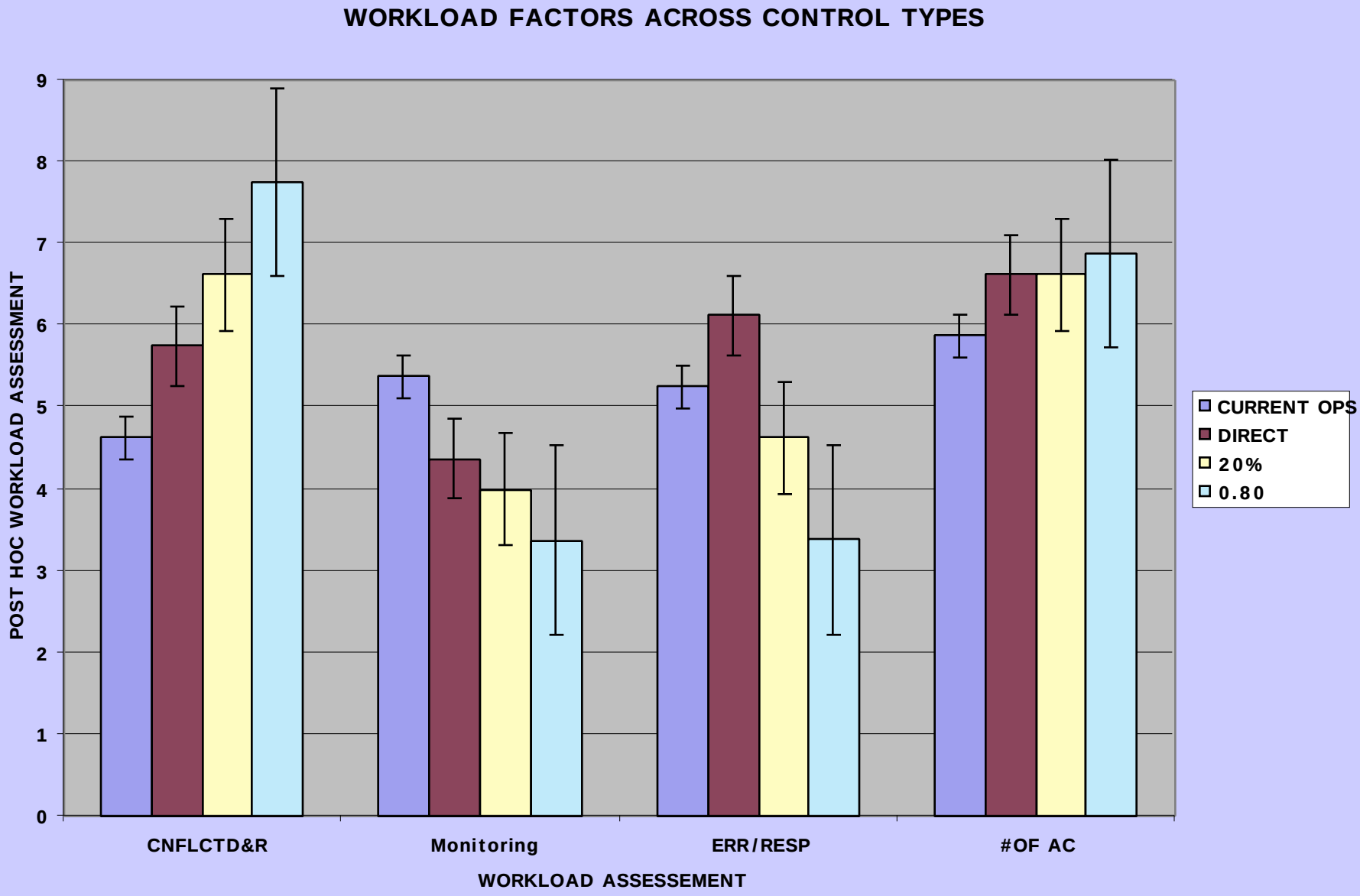
- Taskload Regression Analysis
- Post Hoc Workload Analysis
- Communications Analysis
- Operational Analysis
- Summary

Experiment Results:Regression

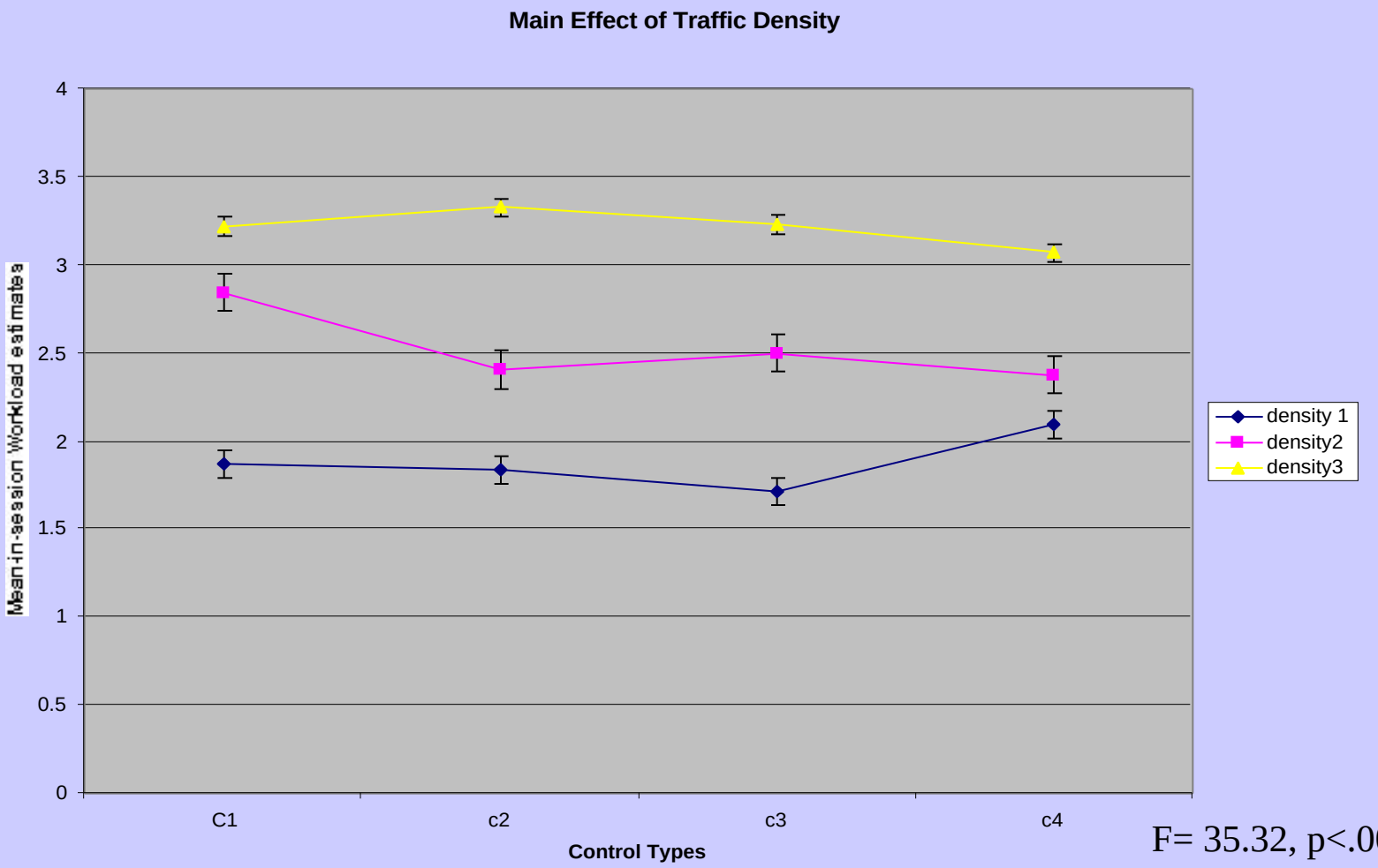
- Regression Equation for Workload across dependent variables:
  - *Workload is the subjective evaluation of the controller on a scale of 1-5 with respect to how busy he/she is.*
  - *Latency is the amount of time it takes the controller to respond to the on-screen prompt to record the workload level.*
  - *Aircraft are the number of aircraft under control or self-separating at the time workload is recorded.*
  - *Comtime is the amount of communications time, measured in minutes, between the controller and the aircraft for each 5 minute period.*
  - *DifctABC_D is the difference in communications time for each 5 minute period between exercises AB and D.*
  - *DifctABD_C is the same measurement between exercises AB and C.*
  - *Acslow is the difference between fast moving aircraft and slow-moving aircraft measured by the number of slow-moving aircraft for each 5 minutes.*
  - *Hoac is the number of aircraft waiting for handoff per 5 minutes.*

(eq 1) workload = 0.578 + 0.0102 latency + 0.0546 aircraft + 0.441 comtime + 0.477 difctABC_D - 0.136 difctABD_C + 0.0951 acslow + 0.0804 hoac

Summary Workload Estimates Post Hoc

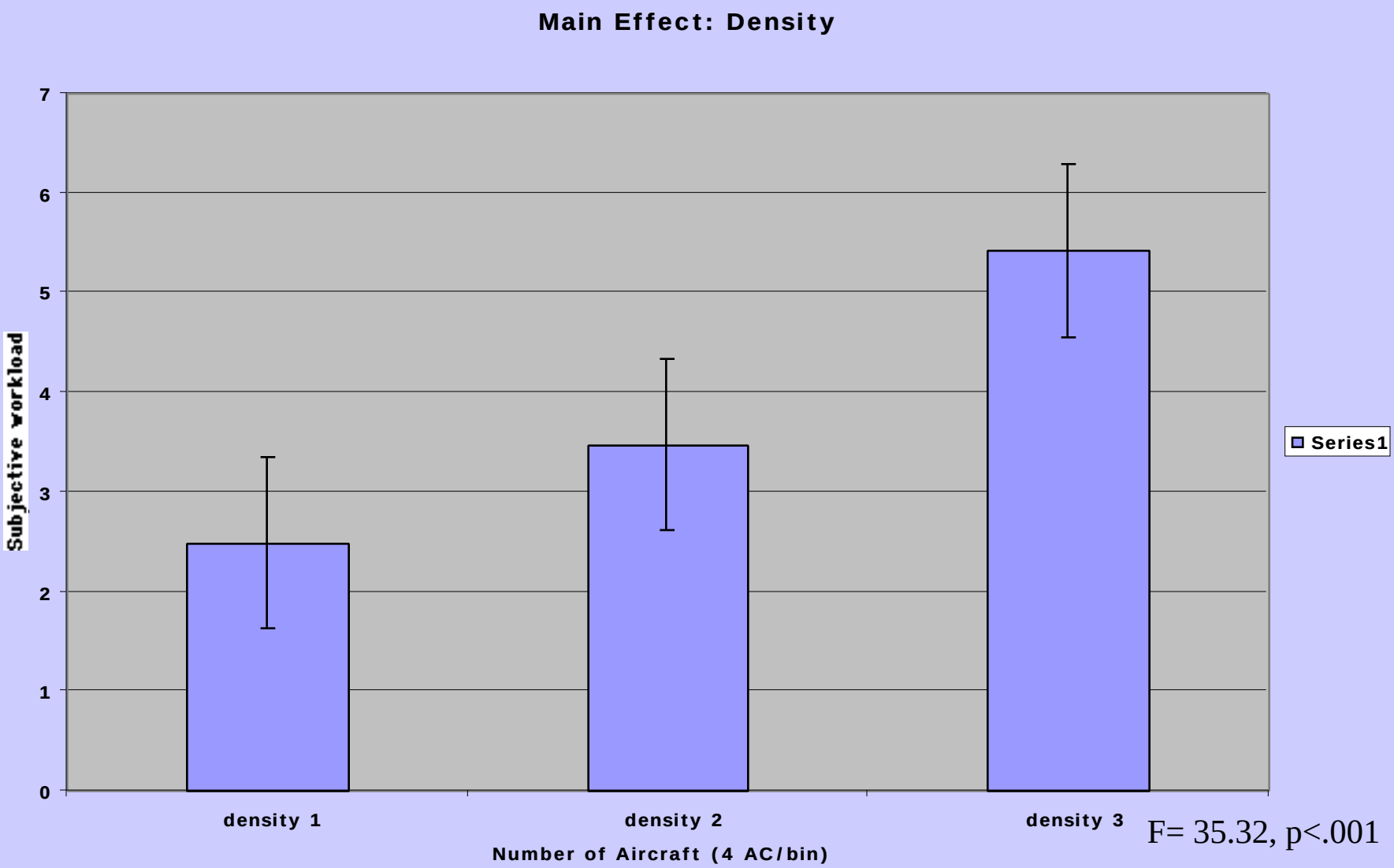


Main Effect of Traffic Density on Subjective Workload: In Session



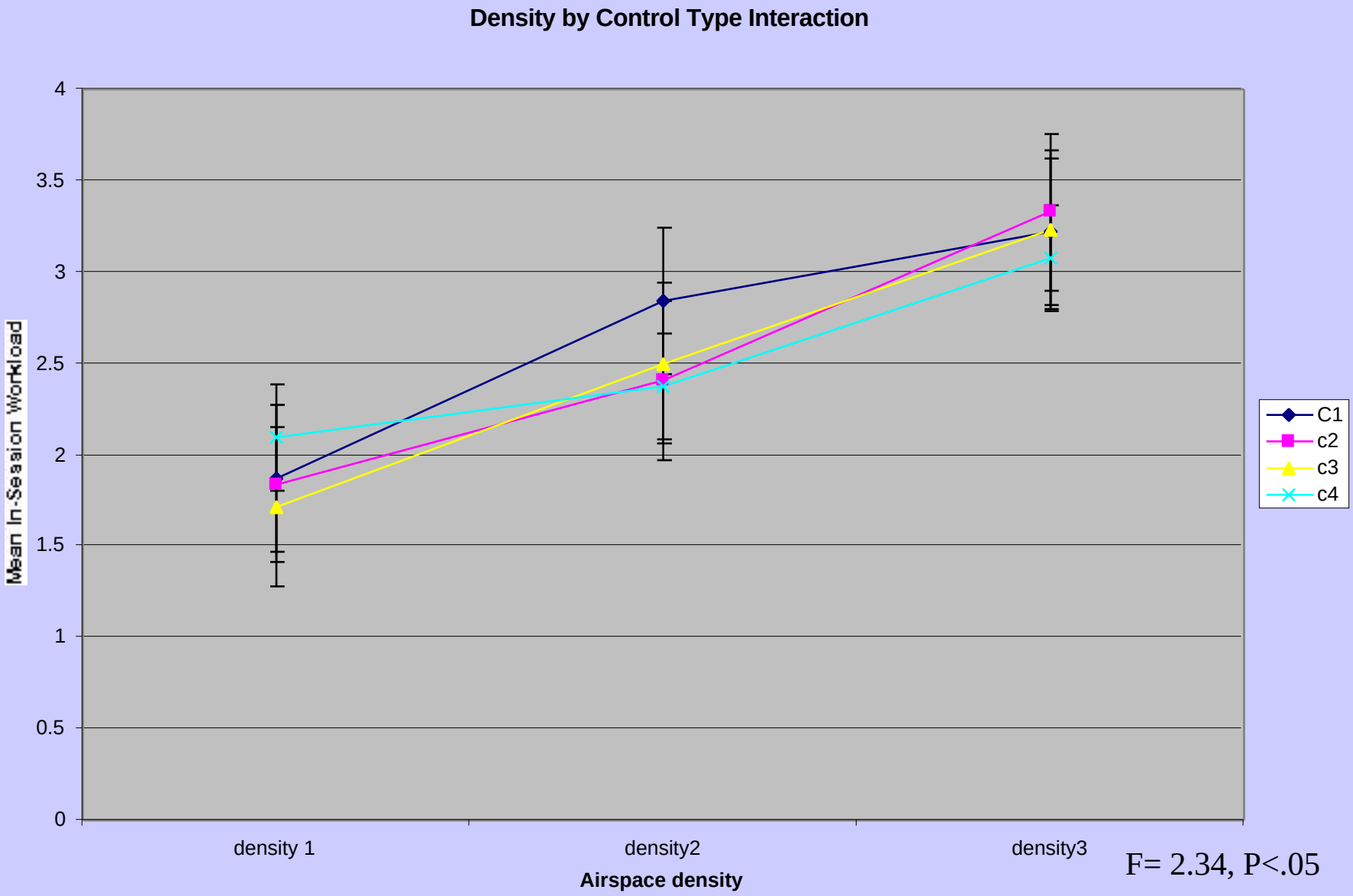
F= 35.32, p<.001

Main Effect of Traffic Density on Subjective Workload: In Session



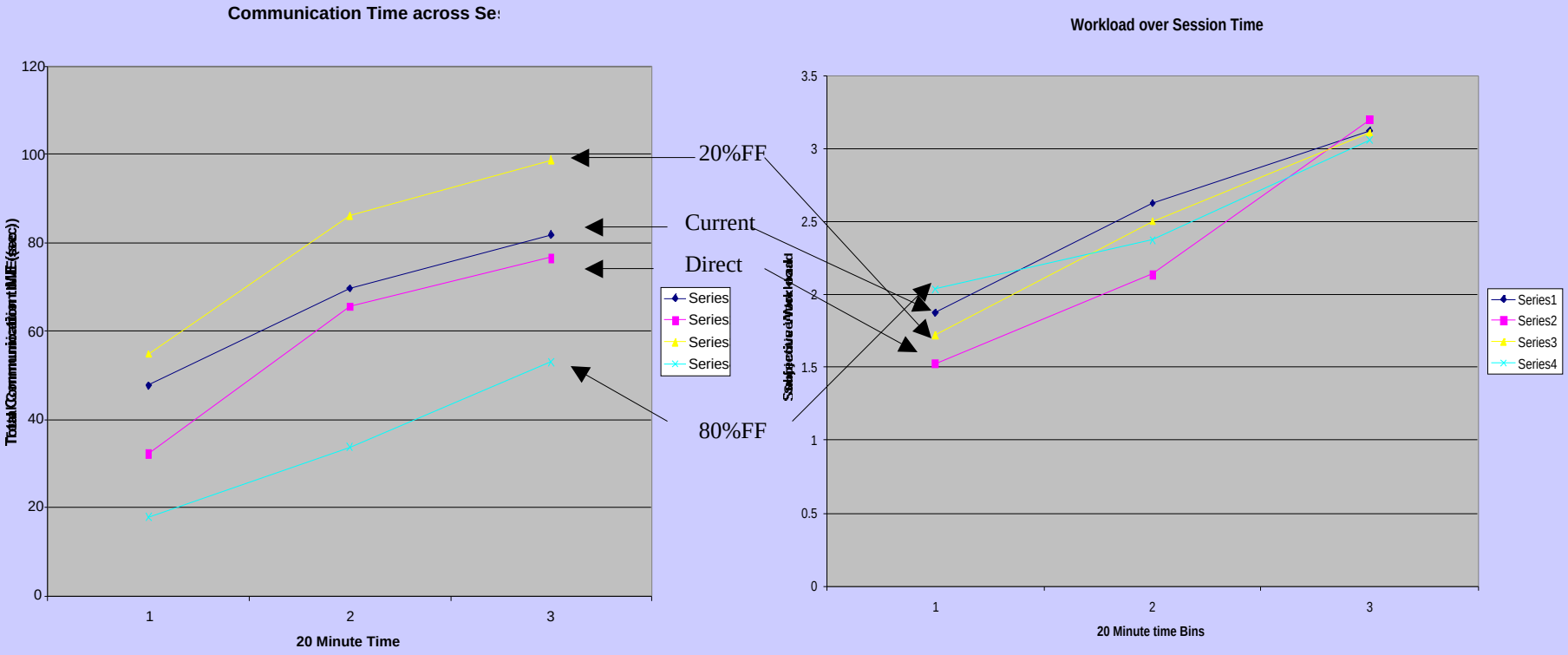
F= 35.32, p<.001

Interaction Effects Traffic Density

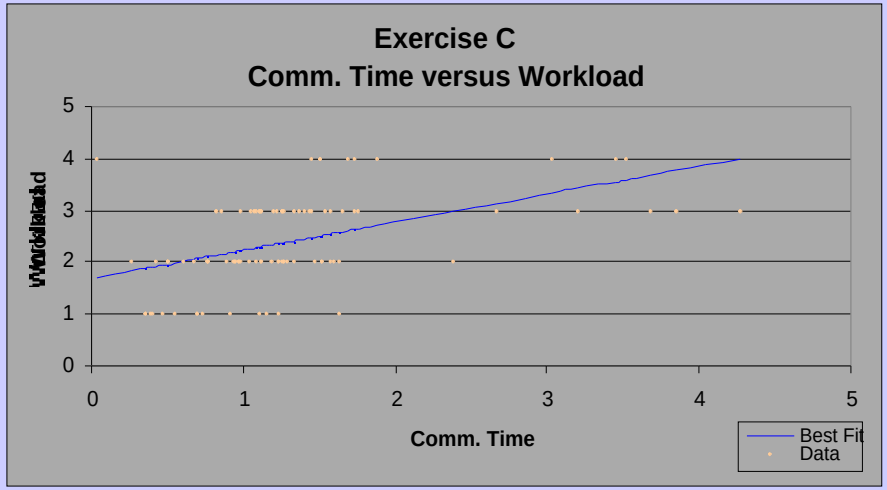


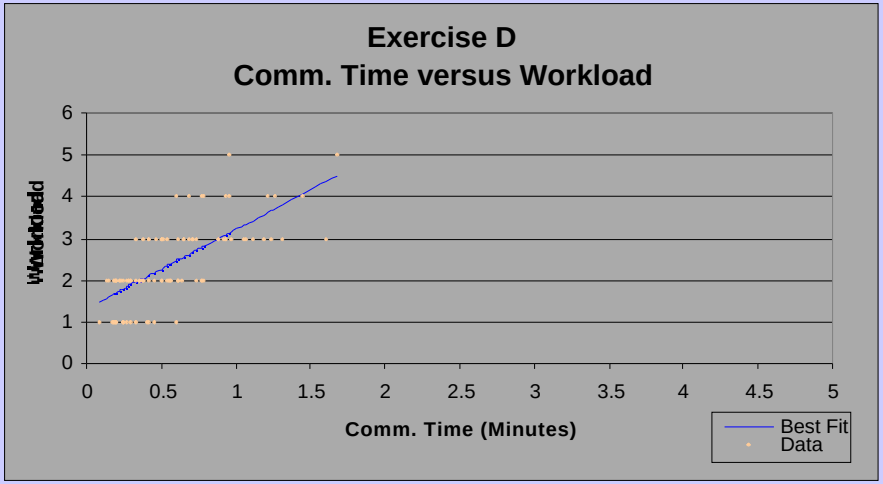
F= 2.34, P<.05

Experiment Results:Communications



Communications Load





20 % Self-Separating Aircraft

80 % Self-Separating Aircraft

Experiment Results:Cancellation of Free Flight

		Cancellation of FreeFlight				
	Exercise C, 20% SelfSep			Exercise D, 80% SelfSep		
Controller#	Number Self-Sep Controlled	Number Returned to Self-Sep	Ave Time To Return Control (sec)	Number Self-Sep Controlled	Number Returned to Self-Sep	Ave Time To Return Control (sec)
1	2	2	344	4	1	29
2	2	0	N/A	3	3	294
3	0	0	N/A	5	4	213
4	6	5	N/A	6	3	237
5	1	1	558	4	1	217
6	3	2	105	4	3	273
7	4	3	68	2	2	62
8	1	1	52	2	0	N/A
Average[1]	2.4	1.75	225	3.8	2.125	189
WeightedAve[2]			122.0			213.0
Percent of Flights[3]	20%			9%		

Notes:

[1]Average represents average over contollers

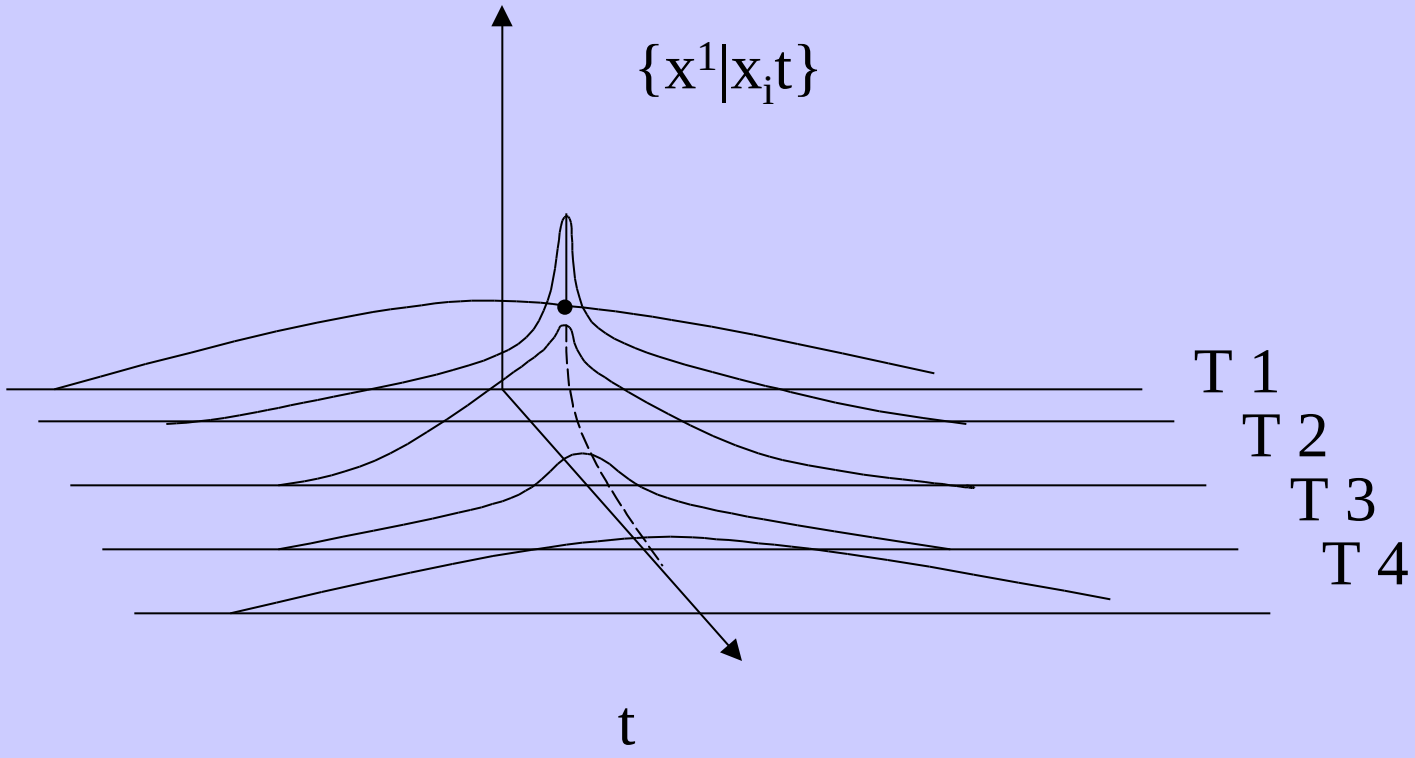
[2]Weighted Average is the average time per aircraft that self-separation was revoked

[3]Percent of Flights is (Number Self-Sep Controlled)/(Total Self-Sep)

Theoretical Structure for Results Context and Control

- **Scrambled Control**: In which the choice of the next action is unpredictable or random. The operator seemingly does not have a useful internal model of the world in which they are taking action.
- **Opportunistic Control**: Opportunistic control corresponds to the case where action is taken based on the current context. The current context in these terms is perceptually salient features or patterns as opposed to more fundamental constructs such as intentions or goals.
- **Tactical Control**: Tactical control is characteristic of situation where operator performance is based on some kind of planning. This is behavior that is consistent with the rule-based levels of control identified by Rassmussen.
- **Strategic Control**: Strategic control is that condition under which the operator has a sufficiently accurate model of the controlled process and the environment in which that control is undertaken to support planning and prediction in support of high level goals that can be managed across a system of interruption.
- (Hollnagel, 1993, 1997)

Information Sampling Theory *



* Sheridan, 1970

Relation to Previous Work

- Related work:
  - Endsley & Stein (1997), Endlsley (1997)
    - Increased controller workload in free flight operations
  - Mogford (1998)
    - Situation Awareness Information requirements for Controller operations
  - Cashion and Lozito (1999)
    - Intent type: no significant behavioral effects for intent type (FMC intent preferred)
  - Endsley, Stein and Sollenberger (1999)
    - Exploration of the requirements for intent

Proposed Further Investigation

- **Investigate different allocations of information for tactical and strategic operations.**
- Strategic intent: 3-D dimensional representation of the flight path of the aircraft displayed as a dimmed line showing the planned route with altitudes and times at various fixes.
- Tactical intent: intent vector would include course, next turn point, potential conflicts, air speed (current and requested), climb rates when initiated.
- Potential conflicts: Potential conflicts will provide automatic display with both aircraft tactical intent with the position and time of possible conflicts.
- Negotiated settlements: Other relevant information, such as notification of the controller that the aircraft were in contact with one another and assuming evasive action could also be included in this display. These issues are of direct importance to the nature of the ATSP display envisioned by the DAG-TM.
- **Investigate different roles for controller team and different procedures associated with the information distribution**